

METHOD AND APPARATUS USING MICROWAVE ENERGY

FIELD OF THE INVENTION

The present invention relates to a method and/or apparatus for converting and/or generating energy from any organic material into a more usable energy by means of microwaves. In one
5 form the invention teaches a method for converting an organic material such as organic waste or a food item into heat energy, plasma energy, high-pressure energy, electric energy or other useful forms of energy.

More particularly, the present invention relates to a process that uses microwave energy to generate a higher level of energy from any organic material. The microwave energy used can
10 be of any frequency from 500 MHz up to but not limited to 5000 MHz. Thus an organic waste for example, may become a source of renewable energy preferably in the form of plasma to generate heat, plasma energy, electricity, high-pressure and perform various types of work.

BACKGROUND OF THE INVENTION:

15 Energy of any type like heat, high-pressure, electricity etc. is essential for sustaining life and for industrial development. At present, the most common source of energy is either fossil fuel or hydropower. The sources of fossil fuel are limited and are non-renewable. Fossil fuels are not available everywhere. Hydropower is also limited, not available everywhere and dependent on weather conditions and lake levels. Natural energy resources like wind energy,
20 solar, geo-thermal etc. have been harnessed to some extent, but they can not be stored. Importantly, we do not have control of the sources of these natural energy resources and there are limitations with the current technology to convert energy from natural resources into a useful, efficient form of energy.

Before the use of fossil fuels such as petroleum and gas, the most common source of energy
25 was animal power. However, it is neither efficient nor convenient to convert this animal or muscle energy into other forms of energy. Simply put, animal or muscle energy is basically obtained from food sources. A food item is generally an organic material, which grows with the help of water, air and solar energy. Presently, there is no convenient or efficient technology available to convert a food item into another directly useful form of energy.

Thus, there is a long felt need to devise a method for converting and/or generating a useful form or forms of energy from organic material, and most preferably from waste or non-useful organic material, such as waste food items, or inedible or at least the non-eaten parts thereof.

5 Microwaves were first used by man in the radar that was developed prior to the Second World War. Today microwaves are used in such varied things as broadcasting, surveillance, cell phones, airport scanners and, of course, the domestic microwave oven. Microwaves are used to cook food in microwave oven by the fact that, although the microwaves are reflected by metals, they are absorbed by foods and penetrate instantly into a food.

10 As discussed above, microwave energy is used for heating food items. Further, It is known that many materials absorb microwave energy. Fundamentally, the temperature of an item increases with the absorption. The rate of absorption is a function of the type of material, some materials completely reflect the microwave energy, i.e. they do not absorb any microwave energy. The microwave energy is mostly used for heating or communication purposes. A technology to generate more energy utilizing the microwave energy is not
15 available.

In just about every industrial application, waste heat is constantly generated and released into the ambient environment. The amount of this waste energy is huge. The exhaust waste heat is considered as relatively low in temperature and it is difficult to recover this heat for any practical purpose. Significantly, there is no technology available to use this heat for any
20 economical advantage.

A significant portion of food is thrown as waste; this waste is an organic waste. In many countries this waste is eaten up by animals, that basically converts into animal energy or animal muscle power. Thus, organic waste has a potential for conversion into energy. It is possible to convert this waste into useful energy. Moreover, an organic material is grown on
25 plants and is always available on a periodic cycle. It can be a source of renewable energy, because organic food material is renewable. The existing technology for conversion into energy is a slow process, which takes long time to convert organic material into useful energy.

Thus, it appears that the prior art processes are deficient in that they mostly use non-renewable fuel. They do not provide a suitable means of using the organic material or waste heat from industrial activities to generate more energy.

The exhaust emissions from known petro-chemical combustion processes contain a myriad of
5 different type of harmful gases.

OBJECT OF THE INVENTION

It is an object of the present invention to provide a method and/or apparatus for confining, converting and/or generating an organic material or organic materials into a usable form of energy by means of microwaves, and whereby at least a portion of the mass of the organic
10 material is converted into usable energy.

It is a further object of the invention to provide a method and/or apparatus for measuring the energy value inherent in an organic material or materials by means of microwaves.

DISCLOSURE OF THE INVENTION

Accordingly, in its broadest aspect, the present invention provides a process to obtain a new
15 source of renewable fuel and energy. The invention provides an energy conversion system, which is capable of converting an organic item into a useful form of energy. The exhaust of this energy conversion system is comparatively less harmful.

The mass of the residue left after the conversion process is less than 20% by weight of the original mass of the organic material.

20 In another aspect, the present invention provides for a process for converting and confining an organic material into high temperature plasma utilizing microwave energy as a source of input energy. It provides a new process to generate plasma for many other applications.

In yet a further aspect of the invention there is provided a method and apparatus for converting organic material into a fuel wherein the fuel, once prepared into in an appropriate
25 form is exposed to microwaves and transformed into usable energy form.

Preferably, the fuel is exposed to microwaves under a switching or valve control such that the temperature and pressure generated is able to be maintained within desired parameters.

Preferably, the preparative steps are monitored to ensure that the conversion of energy from the organic material is maintained at a temperature and pressure in a sustainable and/or continuous manner.

Another aspect of the invention provides for a method for converting organic material into a usable form of energy by means of microwaves the method comprising the following steps:

- (a) Drying the organic material to remove at least 80% of the moisture content whereby the dried organic material is converted into an energy storage form,
- (b) submitting the energy storage form to sufficient and controlled heat to further alter its chemical composition to convert it into a new kind of fuel, and
- (c) exposing this fuel to microwaves to convert the energy contained within the fuel into a usable form of energy selected from thermal, electrical, a high pressure, plasma, ionised air or gas and a fusion energy.

Preferably, the energy storage form is organic material, which is carbonised.

Preferably, the microwave operates at a frequency of 500MHz to 5000MHz and at a power of between 500W to 100 kW. Depending on the power of microwaves and type of material, the plasma is generated within 2 to 400 seconds.

Preferably, the organic material is organic waste or fresh organic matter.

Preferably, the organic waste is selected from chicken, pork or other meat scraps.

Preferably, the organic waste is selected from waste vegetables, peeled skin of fruits, chunks of fruits, manure or compost. In particular, skins of apple, potato or banana.

Preferably, the fuel prepared at step (b) is exposed to microwaves at step (c) in the following manner:

- (i) the prepared fuel is transferred to a glass chamber or a heat exchanger,
- (ii) the glass chamber or heat exchanger is either transferred to, or preferably housed within a microwave cavity or microwave oven,
- (iii) the microwave cavity or microwave oven is actuated whereby the prepared fuel is transformed into a flame or plasma of a temperature above 100°C.

Preferably, the prepared fuel is transformed into a blue flame or plasma of a temperature above 400°C.

Preferably, the energy generated at step (c) is adapted for use in an internal combustion engine equipped with microwave igniters.

- 5 Preferably, the energy generated at step (c) is adapted to be used in heating or cooling system.

Preferably, the energy generated at step (c) is adapted to be used to generate a high temperature plasma of above 100°C.

- 10 Preferably, the plasma initiator such as copper wire, iron, tungsten, metal or non-metal initiator may or may not be used to initiate the process of plasma generation. The energy efficiency and response time of the process is a function of the presence or absence of the plasma initiator. Depending on the type of organic material used, the process is successful even in the absence of plasma initiator.

Preferably, the energy generated at step (c) is adapted to be used to produce plasma, the plasma being available for use in a Magneto Hydro-Dynamic (MHD) process.

- 15 Preferably, the glass chamber or heat exchanger is optionally fed by a gas or air stream.

Preferably, the MHD process is adapted to generate electric power from plasma and the resultant ionised air atmosphere either using a permanent magnet or electromagnet or by inducing an electric current within a conductive coil such as copper.

- 20 A still further aspect of the invention provides for a method for determining the energy value of a food item wherein the organic material is a food material and wherein after said material is prepared via steps (a) and (b) and exposed to microwaves at step (c), said material is transformed into a plasma, the properties of plasma generated being a measure of the energy value of the organic item.

- 25 Preferably, the plasma properties used for determining the energy value of the food material are selected from (i) the colour of the plasma generated and (ii) the volume of the plasma generated and (iii) the air pressure generated, (iv) temperature of the plasma and (v) the efficiency of plasma generation.

An additional aspect of the invention provides for the situation wherein plasma generated at step (c) is confined within the glass chamber or heat exchanger used at step (b) and is available to be harnessed or extracted for further use.

Preferably, the further use is use in an internal combustion engine, to power a heating or cooling system, or to be further converted into thermal, electrical or high pressure energy, or returned to a central electrical system such as a national grid

In a still further aspect of the invention there is provided an apparatus useful in a method according to any one of the preceding claims, the apparatus comprising:

- (a) a microwave cavity or microwave oven
- 10 (b) housed within the microwave cavity or microwave oven is a glass chamber, or a heat exchanger,
- (c) optionally an inlet for providing a gas or air stream, preferably heated, to the glass chamber or heat exchanger,
- (d) a means for harnessing or extracting the thermal, electrical, high pressure, plasma, ionised gas or air, or fusion energy generated within the cavity, and
- 15 (e) an outlet for exhaust gases.

Preferably, the means for harnessing plasma or ionised gas or air, generated at step (c) of the method comprises a coil of any conductive material such that when in contact with the ionised particles of plasma an electric current is induced or generated. This current induction creates a reactive force to confine the plasma, which helps to harness its energy.

Preferably, the gas stream is air or oxygen, or a combustible oxygen mix.

Preferably, the apparatus is adapted for fitment and use in an internal combustion engine.

Preferably, the present invention provides an energy conversion system, while adapting to an industrial facility, the energy conversion system is capable of storing energy from industrial exhaust waste heat, and supply the stored energy in a usable form at the time of need.

It is yet another aspect of the present invention to adapt an internal combustion engine of a vehicle or otherwise, in which an organic item is used as a fuel. Preferably, a source of microwave energy ignites an organic fuel to generate a high-pressure air explosion, wherein

the high pressure air explosion provides the mechanical power output for an internal combustion engine of a vehicle or any machine.

It is an additional aspect of the invention to provide a process to adapt an ionized air generation system, wherein the thus adapted ionized air generation system is used in a
5 Magneto-Hydro Dynamic system to generate electric power from plasma and ionized air. This ionization process provides an efficient conversion of food item into energy, with minimum emissions of polluting products. The subsequent ionization of air due to microwaves minimizes the polluting emissions and it is possible to further reduce these emissions by the use of magnetic resonators.

10 Still another aspect of the present invention is to provide a process, wherein a magnetic field is used across a chamber of ionized air to generate electric power. An ionized air or gas is generated due to the exposure of processed organic item to the microwave energy.

It is yet another aspect of the present invention to provide a process to heat and melt plastic for injection molding by converting an organic item into heat energy utilizing microwave
15 energy for the conversion.

The present invention provides a process to utilize the waste heat from any other processes. The waste heat from other processes is used to pre-process an organic item to remove moisture and pre-heat it to a desired form or consistency.

It is an additional aspect of the invention to provide a process to adapt an energy conversion
20 system, which feeds back a fraction of energy output to microwave oven or microwave energy generating device. Thus, an energy conversion system which is a self sustaining continuous process, wherein an organic item is continuously fed as fuel for conversion to a more usable energy.

The invention provides a process to adapt a portable engine based on microwave system, to
25 convert a new kind of fuel into energy. The fuel is very safe to carry around, because it does not catch fire with normal sparks, electrical shorts, cigarettes, or normal ignition. Whereas, a conventional petroleum product / fuel is a hazardous chemical and it is prone to catch fire by sparks etc.

DEFINITIONS

Plasma may be defined as the fourth state of matter wherein matter is found in an energised, excited and/or in a form of gaseous mixture of positive ions and electrons.

Efficiency of plasma generation is measured by the amount of microwave energy required to
5 convert a given amount of an organic material into an energised plasma.

Organic Material as applicable to this invention relates to any organic material other than purely hydrocarbons and includes organic matter, which is essentially derived from living, biological or waste organic matter.

BRIEF DESCRIPTION OF THE DRAWING

10 Embodiments of the present invention will be described with reference to the following figures:

Fig. 1 is a schematic diagram of pre-heating a food item to remove its moisture content and carbonize the item in the presence of air..

Fig. 2 is a schematic diagram to expose the pre-processed item into a microwave energy
15 chamber. The food item converts into plasma, heat energy that is useful for heating or conversion into another forms of energy by self-sustaining process.

Fig. 3. is a schematic diagram to show the use of MHD and magnets for direct conversion of plasma of ionized particles, which can be converted into electrical energy.

MODES FOR CARRYING OUT THE INVENTION -

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PREFERRED EMBODIMENTS:

The present invention provides for an energy generating and/or conversion system, wherein an organic item or an organic waste, preferably a vegetable, fruit, meat scrap, manure or compost is heated by a conventional heat source or from an exhaust waste heat source, to convert a the food item into a new kind of fuel. This new fuel can be converted into a more
25 usable higher level of energy on exposure to microwave energy.

The energy conversion system converts an organic material into a new kind of fuel. The energy generated from this fuel is many times greater than the input energy. The process provides a new source of renewable energy; the organic material is obtained from the normal fruits and vegetables. The material is renewable, because it's organic source is renewable and
5 optimally may be cropped year after year, season after season. An organic food item or waste from a food item is subjected to this innovative process to covert it into a combustible fuel. The organic material converts into energy only if exposed to microwave energy. The organic material is heated to remove a majority of its moisture content, preferably, 80% or more. After drying, the organic material is further heated very carefully at a controlled temperature
10 to carbonize the material to a form that is both immediately usable or may be stored, if necessary for years. After being so prepared the fuel is ready for the next stage of the process.

The carbonized material is now transferred to a glass chamber designed as a heat exchanger or an internal combustion device or other appropriate device to generate electricity. The glass
15 chamber is placed under the source of microwave energy, wherein the carbonized material starts absorbing the microwave energy. Under the microwave energy, the material gets ionized and burns, often with a blue and bright flame of very high temperature. This ionized atmosphere with blue flame generates heat energy, high-pressure energy, electro-motive energy or other kind of energy to produce work for other applications. Importantly, this
20 high-energy plasma is confined within the glass chamber and captured for immediate or later use. The carbonized food item is ionized under the microwave energy, which generates an ionized atmosphere similar to Plasma. When this ionized atmosphere is placed under a magnetic field of two magnets, it will produce electricity, following the principle of Magneto-Hydro-Dynamics (MHD). Thus, the process may be used to generate ionized gas/
25 air for a MHD system to produce electricity like an electric generator. The amount of energy output depends on number of factors like developed air pressure, type of organic item, microwave energy level etc. The net output energy level is more than the input energy. With an automatic mechanical system, this process becomes a self-energy sufficient and sustaining operation. An electro-mechanical system introduces the pre-carbonized and converted food
30 item into a device, placed inside a microwave cavity. This mechanical system also controls the waste exhaust, control of microwave operation and the net transfer of output energy to produce work.

The process is also a new process to generate high temperature plasma. The use of plasma initiator such as copper wire, tungsten, metal or non-metal compound moderates the efficiency and duration of the process. It is not necessary to use a plasma initiator. If required, it may be used to modify the performance parameters of the process

- 5 The invention also relates to a method to determine the nutrition value of an organic material. While studying the conversion of food item into energy using microwave, it was discovered that amount of microwave absorption depends on the properties and composition of various organic items, in particular food items. A food item generally considered to be nutritious absorbs higher amount of microwave energy. Consequently, a waste from a nutritious food
- 10 item produces energy more efficiently. Thus a nutritious food generates more energy within a given item, this energy output then measures the nutrition value of the food item.

Apparatus - Industrial Applicability:

The foregoing apparatus are illustrative only and, where specific integers are mentioned which have been known equivalents, such equivalents are deemed to be incorporated herein

15 as if individually set forth.

The process involves a preparative step wherein a fresh or waste food item is pre-heated to convert it into a more usable fuel. This step is termed as "Energization" of the food, and is illustrated in Fig 1. Preferably, the energization process heats the food item at a relatively low heating temperature, which evaporates the moisture content completely. In a preferred

20 embodiment of the present invention, there is provided a energisation process as shown in Fig. 1, comprising the steps of:

- (a) An organic, organic waste or food item is placed in an oven 2 in the presence of fresh air 3 and heated via a heater 1 at low temperature, or from source of waste heat 5. This heat evaporates and exhausts 4 the majority and preferably
- 25 substantially, all of the moisture content of said organic, organic waste or food item. Heat input 5 from any source of waste heat increases the energy efficiency;
- (b) Further heating this dried item to carbonize under controlled temperature by heater 1, without generating fumes and without burning the item.

- (c) the organic, organic waste or food item is now converted into an energy storage form. The fermentation process of the item is now stopped and even a prolonged period storage of this storage form will not alter its properties;
- 5 (d) Thereafter, the storage form is submitted to sufficient heat to alter its chemical composition, by increasing the temperature of heater 1 for a short duration of few minutes,
- (e) The item is now converted into a new kind of fuel suitable for conversion into energy using microwaves.

10 Throughout the specification the terms organic, organic waste and food item are understood to be substantially interchangeable and for the purposes of the remaining embodiments, descriptions and examples reference to food item will encompass all of the above variations.

In a preferred embodiment of the present invention, the energisation process converts a food item into a new type of fuel, which can be preserved or stored indefinitely. It is preferred that the item is not burnt or converted into ash in the above process.

15 Preferably a food item is waste skin of a fruit or vegetable.

Preferably, the exhaust waste heat is heat derived from an industrial activity, a vehicle, machine or from a cooking or drying process. The hot air from exhaust waste heat circulated on a food item will remove its moisture and, depending upon the temperature of waste exhaust heat, the food item can be processed at a very low cost.

20 The important fact is that exhaust waste heat is stored in the food item to be released at any desired later date at the time of exposure to microwave energy.

The next step according to the present invention is to expose the prepared fuel to microwave energy.

25 Preferably, the microwave energy is of any frequency from 500 MHz to 5000 MHz. The power of microwave energy can be a pulsed or continuous power, ranging from 100 watts to 100 KWatts. The input energy is used to generate higher level of output energy, i.e. the input microwave energy converts the fuel to a higher level of output energy. As shown in Fig. 2, the process comprises the following steps:

- (a) The converted and prepared fuel from process of Fig.1 is transferred to a Pyrex-glass or high temperature ceramic chamber 2, which has a suitable safety pressure release and exhaust valve 10. To moderate the process, the plasma initiator is placed along-with the fuel;
- 5 (b) This chamber is in thermal contact with a non-metallic heat exchanger 3. The combination is placed in a microwave cavity or a microwave oven 1;
- (c) Microwave energy is switched on and within 2 to 400 seconds this fuel converts into a blue flame or hot plasma of temperature higher than 100°C. The time taken is a function of the type, amount of item and microwave level. The heat exchanger 3 could be an internal combustion engine or MHD system with a circulating duct for plasma.
- 10 (d) Preferably a process to feed an air stream to a glass chamber or a heat exchanger by means of an air blower. The heated air stream of very high temperature with exhaust product is delivered for heating applications and for any other suitable energy conversion and distribution system 5;
- 15 (e) Microwave energy is applied under switching control 9 to maintain the temperature and pressure within safe limits of the complete process;
- (f) Process is monitored to control the energy extraction, control 9 the microwave energy, while maintaining the pressure and temperature to sustain the process.
- 20 (g) For continuous and self-sustaining process, the prepared fuel is fed from hopper 11 via valve 12 and spent solid residue is discarded through valve 4. Preferably the process is under complete control by switching and pulsed operation of microwave energy. Microwave is switched off during the exhaust and fuel injection cycle.
- 25 (h) The heat or electrical energy received at 5 converts into a useful form for delivery to energy utility system 6 such as an electrical national grid or industrial processes.

- (i) A fraction of the energy output at 5 is converted into electrical energy, which in turn drives the source 8 for microwave energy. The feedback system 7 delivers fraction of output energy through an auxiliary power source 8 for microwave energy. As shown in fig. 2, an initial source of energy 8 is required to start the microwave source and initiate the process. Input food item is converted into energy, a fraction of which is fed back for microwave source. A continuous supply of food item i.e. fuel will sustain the process. The microwave source can be a pulsed or a continuous source.
- (j) The control 9, auxiliary power source 8 such as an automobile battery and feedback system 7 makes the apparatus a self-starting and self-sustaining system. With lighter parts it becomes a portable energy generating system with the advantage of a non-inflammable solid fuel.

The energy conversion system of the present invention can be adapted for an internal combustion engine equipped with microwave igniters. In this embodiment of the present invention, the glass chamber and microwave cavity is about the same size. The prepared fuel is converted into usable energy and generates high air pressure. The high air pressure is used to drive a piston of an internal combustion engine and provide the power stroke for driving a mechanical system of a vehicle or any machine. The prepared fuel along with air is introduced into an internal combustion engine at stoichiometric ratios suitable for efficient energy conversion purposes.

The exhaust gases resulting from such an internal combustion engine as described above will be less harmful when compared to the gases derived as waste from a petro-chemical internal combustion engine.

A skilled reader will instantly realize that energy generated from this process is a function of air pressure inside the chamber. The high compression ratio of the engine cycle increases the air pressure. When the compression cycle reaches its top end, it maximizes the air pressure. Release of microwave energy at this stage will result in a relatively more powerful down stroke when compared with a conventional. A stoichiometric amount of fuel and air will ensure minimum fumes and maximum energy output.

The present invention in one of its most preferred forms is adapted to convert a food item into a useful form of energy and preferably, uses the waste from raw fruits or vegetables, such as skins and cores. The method envisages using food items when in season and ideally will not require the need to cut down trees. Thus the conversion process provides for a new and renewable source of energy. The process parameters can be controlled for efficient energy conversion with minimum amount of exhaust gases and waste products.

Further, it was found that various organic items absorb microwave energy differently. In any event, it was discovered that a certain class of food items produces a glow of plasma when exposed to microwave energy. The food items produce the plasma glow only after undergoing a particular drying process. On exposure to microwave energy, the item is consumed and converts into the plasma glow. A very small amount of ash is left as residue. This conversion process generates heat energy of very high temperature. The pressure of the surrounding air increases with the increase in temperature. If the pressure of air is not released, it further increases the temperature of glass chamber resulting in an avalanche effect, which may lead to an explosion. Thus, the process is very useful to generate energy of high temperature and pressure.

In this embodiment of the present invention, the process of plasma and energy generation is kept under complete control. With the control of input microwave energy and a suitable pressure release system, the process remains under complete control. Regulating the air pressure, with a pressure regulating system controls the rise in temperature of the process. The rate of flow of water or air or any medium within the heat exchanger further controls the temperature and pressure. Managing the various parameters within the desired limits will control the process of conversion of food item into energy.

Preferably, this process for plasma and heat generation can be utilized for number of different applications:

The increase in temperature of glass chamber is useful to melt plastic and melt other objects with lower melting point than that of glass chamber. It is possible to adapt the process to melt plastic for injection molding machines.

As a further embodiment of the present invention and as illustrated in Fig. 3, the method and apparatus can be adapted to directly generate electrical energy through a MHD system built

around this process of plasma generation. It is a known fact that plasma exhibits the electrical properties of transition of charged particles such as electric current. The process is a means for generating ionized air atmosphere of plasma that is useful in Magneto Hydro-Dynamic (MHD) process. The MHD system comprises of a Pyrex-glass duct 1 to circulate the plasma
5 2 with velocity U in the direction as shown. Duct 1 is placed within the magnetic field B generated by North 3 and South 4 pole of one or more permanent magnets or electromagnets. Electrical field E with voltage polarity 5 is developed across the pair of metal electrodes 7 placed on the duct 1. The direction of each vector 6 is as shown. Once applied, to the magnetic field, it is possible to use the process of present invention putatively for further
10 development of MHD based systems for the generation of electrical energy.

The process of plasma generation is further applied for the plasma confinement. The plasma generated from the above mentioned process tends to vibrate or oscillate or moves randomly in all the directions. A further embodiment of the process is to confine the plasma for its efficient use. To confine the plasma within a limited direction, the process uses a coil of
15 copper or any conducting material that may or may not be placed in a magnetic field. The glass chamber with food item may be placed in the vicinity of the coil, it is possible to place the glass chamber within the coil or the coil can be placed within the glass chamber. As per the Faraday law of induction, the vibration and rotation of ionised particles of plasma induces electric current in the coil. This induction of current inside the coil generates a reactive
20 magnetic field that applies an equal and opposite force on plasma particles. This method of plasma confinement controls the random movement of ionised particles and enables the harnessing of energy inherent in such plasma. It is possible to use this method of plasma confinement to confine the random motion of ionised particles for all other known methods of plasma generation.

25 Throughout the description and claims of this specification the word "comprise" and variations of that word, such as "comprises" and "comprising", are not intended to exclude other additives, components, integers or steps.

While the preferred embodiment of the invention has been illustrated and described, it will be appreciated that various changes can be made therein without departing from the spirit and
30 scope of the invention.